Missouri Department of Natural Resources
Water Pollution Control Program

Total Maximum Daily Load (TMDL)

for

McDaniel Lake
Greene County, Missouri

Completed: December 30, 2003
Approved: February 3, 2004

Draft Total Maximum Daily Load (TMDL)
For McDaniel Lake
Pollutant: Algae

State map showing location of watershed

Name: McDaniel Lake

Location: Near Springfield in Greene County, Missouri

Hydrologic Unit Code (HUC): 10290106-050001

Water Body Identification Number (WBID): 7236

Missouri Lake Class: L1[1]

Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Aquatic Life and Human Health [associated with] Fish Consumption
- Warm Water Fishery
- Drinking Water Supply

Size of Impaired Segment: 300 lake acres

Location of Impaired Segment: Dam in NE¼, SE¼, Section 26, T30N, R22W

Pollutant: Algae

Pollutant Source: Agricultural and urban nonpoint source runoff

TMDL Priority Ranking: Medium

1. BACKGROUND AND WATER QUALITY PROBLEMS

Area History[2]:

Even before Missouri became a state on August 10, 1821, settlers were arriving in the area that would become southwest Missouri. Claims by the Delaware, Kickapoo, and Osage Indians, however, prevented any type of permanent settlement. It was not until after 1830, date of the Indian removal, that the future Greene County was opened for settlement. The county itself was named for Revolutionary War hero, Nathaniel Greene. It was officially established on January 2, 1833, and its

[1]Class L1 lakes are lakes used primarily for public drinking water supply. See Missouri Water Quality Standards (WQS) 10 Code of State Regulations 20-7.031(1)(F). The WQS can be found at the following uniform resource locator (URL): http://www.dnr.mo.gov/wpscd/wpcp/wqstandards/wq_standard_hm.htm
[2] The Greene County Missouri Historical Society's Home Page, *A Brief History of Greene County*, http://www.rootsweb.com/~gcmohs/ghs2.htm

boundaries encompassed most of southwest Missouri that had been a part of Wayne County to the east. Greene County's present boundaries were finalized in 1858. Daniel Boone's youngest son, Nathan, lived in Ash Grove, Greene County. He died in October 1865 and is buried in the Boone Family Cemetery in Ash Grove.

In February 1830, William Fulbright arrived in the Springfield area from Tennessee. He settled on a spot around a spring that later took the name Fulbright Spring. His brother, John, settled around another spring and built a cabin. This spring later became known as Jones Spring. William's brother-in-law, A. J. Burnett, built a cabin on the hill above a nearby "natural well," not realizing that there was already a claim on it. When John Polk Campbell (who had the claim) returned with his family, Burnett relinquished his cabin and resettled at a new site. By 1835, the settlement of Fulbright and Campbell Springs had been named Springfield. To ensure that Springfield would become the county seat, Mr. Campbell donated 50 acres of his tract to the county for county purposes. He had laid off the 50 acres into lots and streets and a public square patterned after Columbia, Tennessee, his birthplace. Springfield was officially designated the county seat in 1835, but this was not finalized until 1836.

McDaniel Lake was constructed by impounding the Little Sac River in 1929 (Figure 1, page 3). The dam was raised to enlarge the storage capacity in 1990. Fellows Lake was constructed in 1957, and its dam raised to enlarge storage capacity in 1992. The primary purpose for both lakes is drinking water. Additional drinking water sources for the city of Springfield include the James River, Stockton Lake, Fulbright Spring and local wells.

Soils and Land Use:

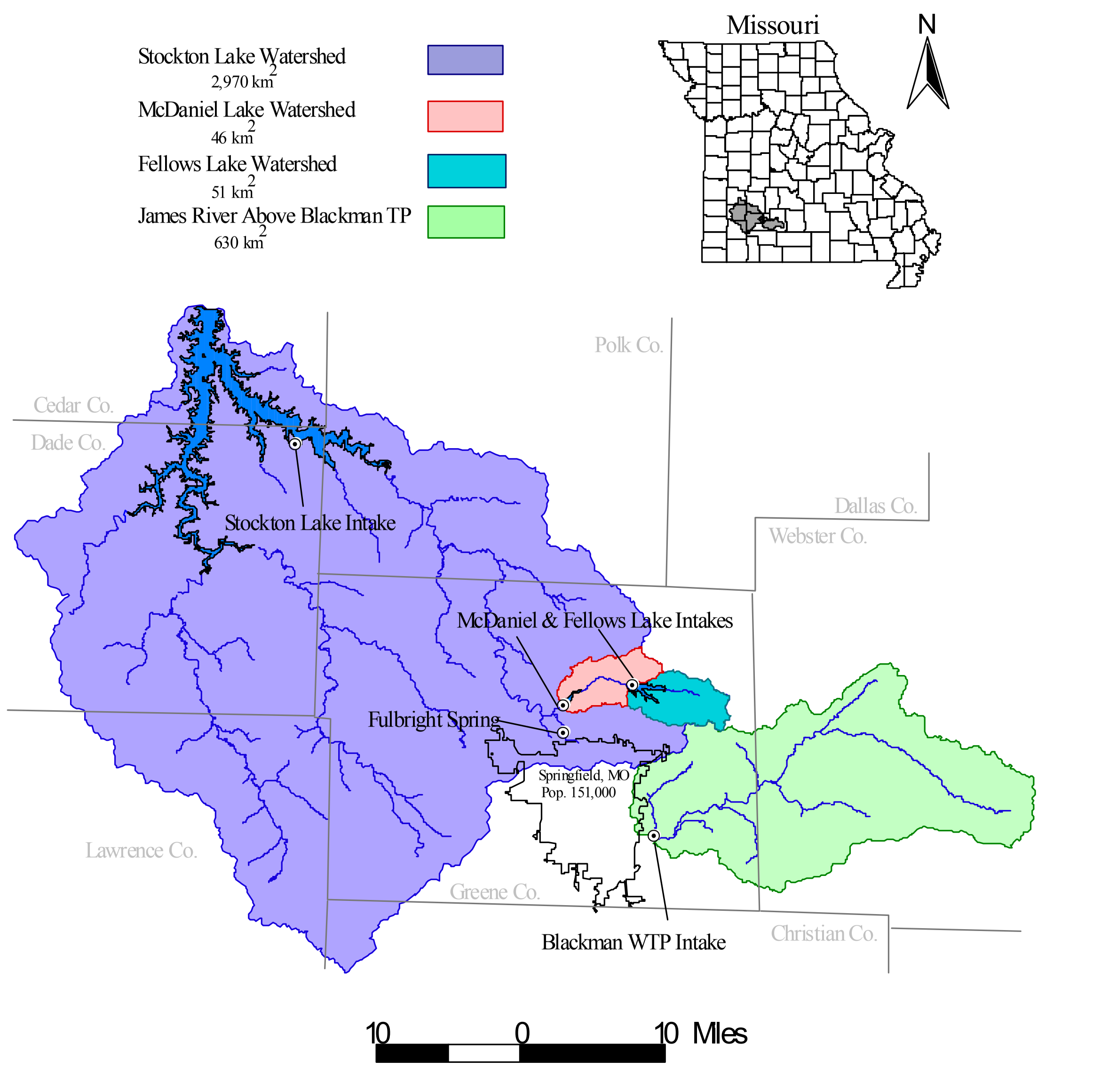
Soils in the upper Little Sac watershed are of two soil associations, the Goss-Wilderness-Peridge and the Wilderness-Viraton. Other minor soils are Huntington, Gasconade, Cedargap and Needleye.

The first association is composed of deep, well drained and moderately well drained, gently sloping to moderately steep soils on uplands and terraces. These soils are used for hay and lumber production and a small amount of row crops.

The second soil association, the Wilderness-Viraton, are deep, moderately well drained soils found on broad upland ridges, narrow flood plains and terraces. They are gently to moderately sloping soils formed in the risiduum weathered from cherty limestone. Nearly all areas are well suited to grasses and legumes and about half are suited to small grain. The major soils have a dense fragipan (soil layer that inhibits water infiltration) at a depth of 15 to 36 inches and, in most years, they have a perched high water table from December to March.

Land use in the upper Little Sac watershed is predominately agricultural, both cropland and pasture. The land bordering McDaniel Lake is mostly wooded and nearly 100 percent of it is owned by City Utilities of Springfield. Land use is shown in Appendix A. This land use data is from 1993 and does not reflect the burgeoning development that is presently occurring in the Fellows and McDaniel watersheds. When new land use data becomes available from the Missouri Resource Assessment Partnership (MoRAP), the TMDL may be reevaluated if significant changes in land use trends are noted.

Figure 1. Area Map



Defining the Problem:

It should be noted that Fellows Lake was also listed for algae on the 1998 303(d) list and the department intended to write a TMDL for that lake along with McDaniel Lake. However, there has been only one taste and odor event[3] in Fellows Lake and no additional data indicate the lake is impaired. Therefore, the department believes that a TMDL is not necessary and is requesting (by a formal letter to follow) that EPA delist Fellows Lake. Nevertheless, Fellows Lake is part of the McDaniel Lake watershed and must be addressed and included in this TMDL.

[3] This observation hinges on the definition of "event." From a water quality perspective, an event is one that is not amenable to ordinary treatment processes, i.e., requires excessive measures on the part of plant operators. When successful these should not result in excessive (more than 10) customer complaints.

Prior to 1982 the City Utilities of Springfield had been receiving customer complaints regarding the taste and odor of drinking water from McDaniel Lake. However, an event occurred in September 1982 that was extensive enough to cause management to address the problem through a long-term concerted program. Initial problems in McDaniel Lake were linked to cyanobacteria (or blue-green algae) metabolites[4], primarily geosmin and 2-methylisoborneal (MIB). Since 1982, taste and odor events were recorded in 1991, 1997-2000, and 2002 in McDaniel Lake. Formations of *Raphidiopsis*, *Lyngbia*, and occasional *Oscillatoria* blooms (types of cyanobacteria) have been linked to contamination issues in McDaniel Lake. City Utility Laboratories use Gas Chromatography/Mass Spectroscopy (GC/MS) to monitor MIB and Geosmin, the cyanobacteria metabolites that impair drinking water supplies during blooms.

Increased production of cyanobacteria is related primarily to phosphorus (P) and nitrogen (N) in the water, abundant sunlight, and warm water temperatures. Relationships connecting the production of MIB and geosmin with water quality and climatic variables are much more complex. The withdrawal of water from Fellows and McDaniel Lakes for drinking water and transfer of water from other watersheds (Stockton Lake and the James River) into the lakes adds another layer of complexity. These activities can alter the water-to-sediment ratio and affect stratification, the natural thermal layering of lakes due to temperature differences in the water. These activities can also affect nutrient storage-and-release from bottom sediments, as well as cause fluctuations in mean lake elevation. Although the above scenario is specific for Fellows and McDaniel Lakes, the paragraph describes the dynamics of a typical drinking water reservoir.

Over the years, City Utilities (CU) has tried many different management approaches to control the taste and odor problem. CU contributed the following information on their activities:

> City Utilities of Springfield has managed to impede the inevitable eutrophication[5] of McDaniel Lake by focusing on the water that enters into that drinking water reservoir. Periodic heavy rains erode soil, nutrients, trash and debris from the watershed tributaries into Fellows Lake (FLL) and McDaniel Lake (MDL). The major causes of eutrophication have been: 1) increased nutrient loading from agricultural sources, 2) urban stormwater run-off of nutrients and pollutants from lawns and septic tanks, 3) improper treatment of wastewater, 4) increased concentration of nutrients in a decreased water volume. All are the result of inadequate watershed management, drought, and continued increased demand for water.
>
> From 1984 until 2002, the results of basic in-lake water sampling did not reveal 1) the primary causes of algae growth patterns despite the relatively low levels of nutrients, 2) what CU could do to control the algae growth or 3) what steps could be taken to reverse the eutrophication of MDL. Agricultural economics and demographics probably accomplished more improvement in the watershed than any planned project. Aging farmers retired, livestock enterprises simply went out of business and urban development began. Except for

[4] A metabolite is a substance produced by metabolism, the complex processes occurring in a cell that are necessary for the maintenance of life. Also, a substance necessary for or taking part in a particular metabolic process.

[5] Eutrophication 1) Natural process of maturing (aging) in a body of water. 2) Natural and human-influenced process of enrichment with nutrients, especially nitrogen (total nitrogen greater than 600 μg/L) and phosphorus (total phosphorus greater than 25 μg/L) leading to an increased production of organic matter [like algae]. Armantrout, N. B., complier. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland.

flood conditions, the phosphorus levels in MDL track an enviable 35 to 45 μg/L. In fact, water clarity has increased to the point that benthic (bottom dwelling) species of algae have become a potential problem. Meanwhile, nutrient levels in the sediments of the mudflats remain problematic and MDL produces geosmin and/or MIB at significant levels in at least 8 out of 10 years.

Zooplankton[6] were in such low numbers historically that CU's limnologist[7] ceased to identify and enumerate them in his weekly sampling scheme. Their low numbers were possibly due to the high population of gizzard shad and/or the predominance of undesirable algae species, and/or a unique major/minor nutrient balance or simply a poor choice of sample location. The city's efforts to reduce the high number of gizzard shad have not progressed beyond discussion. They explored introducing a predator species such as hybrid stripped bass, but did not due to its being a non-native species of fish. Mature carp continue as a problem because they stir the sediments aggressively [and root out any attempt to start vegetation that might compete with the algae].

CU's past lake and watershed management practices include:

- Monthly nutrient testing at selected watershed points.
- Reducing the amount of P, N and sediment reaching the reservoir by encouraging Best Management Practices along erodable tributary banks in the watershed. This has been effective, but there is still too much cyanobacteria.
- Destratification of the layers in the lake. The idea is to keep the lake from getting too warm by mixing the warm and cool layers. Also, the suspended silt that results from stirring up the lake blocks sunlight from penetrating as deep into the water (no sunlight equals no algae). The recent destratification attempt in MDL was mechanically too feeble for good results.
- Evaluation of a chemical treatment by targeting problematic species of algae. Anticipating concerns about algal toxins accompanying taste and odor events, CU chose a proactive approach this year (2003) to an emerging public health issue. They applied CUTRINE®-PLUS[8] to one-third of the MDL surface, to a depth reaching the thermocline[9], at 0.2 parts per million (per label instructions). State usage guidelines affecting the downstream side (Little Sac River below the dam) were "carefully observed by drawing down the lake prior to application. The results of three applications in May, July and September confirmed that problematic species could be controlled while preserving the beneficial algae." They plan to refine the program in 2004 to address some logistical considerations.

[6] Zooplankton are tiny animals that feed on plankton, algae and other tiny plants. These creatures are an important part of the food chain and important in keeping algae levels low. If this layer of the food chain is reduced, algae may increase.

[7] A limnologist is a scientist who studies the life and phenomena of fresh water, especially lakes and ponds.

[8] CUTRINE®-PLUS is a copper compound used as an algaecide/herbicide. According to the compound's literature, the copper in it will not precipitate out or become ineffective in alkaline or hard water. Furthermore, the literature claims CUTRINE®-PLUS can reduce or eliminate taste and odor problems caused by geosmin and MIB producing blue-green algae.

[9] The layer of a stratified lake where the temperature drops rapidly. It lies between the upper, warmer circulating layer and the bottom cold layer.

- Hypolimnetic[10] withdrawal (HLW) in July and August of nutrient-rich waters. CU participated in an initial year-long study to remove nutrients trapped in the hypolimnion. It was believed that this would be beneficial to slowing and perhaps reversing the eutrophication of MDL. They found, however, that HLW seemed to make the lake unstable during the late summer months and that downstream discharge required additional monitoring. Also HLW, used only in the summer, coincided with hot weather and low water volumes in the reservoir, so water supply took precedence over the desire to remove those nutrients.

2. DESCRIPTION OF THE APPLICABLE WATER QUALITY STANDARDS AND NUMERIC WATER QUALITY TARGETS

Designated Uses:
The designated uses of McDaniel Lake, WBID 7236, are:
- Livestock and Wildlife Watering
- Protection of Aquatic Life and Human Health [associated with] Fish Consumption
- Warm Water Fishery
- Drinking Water Supply

The lake classifications and designated uses may be found at 10 CSR20-7.031 (1)(C) and Table G.

Use that is impaired:
Drinking Water Supply

Anti-degradation Policy:
Missouri's Water Quality Standards include the Environmental Protection Agency (EPA) "three-tiered" approach to anti-degradation, and may be found at 10 CSR 20-7.031(2).

Tier I defines baseline conditions for all waters and requires that existing beneficial uses are protected. TMDLs would normally be based on this tier, assuring that numeric criteria (such as dissolved oxygen and ammonia) are met to protect uses.

Tier II requires that no degradation of high-quality waters occur unless limited lowering of quality is shown to be necessary for "economic and social development." A clear implementation policy for this tier has not been developed, although if sufficient data on high-quality waters are available, TMDLs could be based on maintaining existing conditions, rather than the minimal Tier I criteria.

Tier III (the most stringent tier) applies to waters designated in the water quality standards as outstanding state and national resource waters; Tier III requires that no degradation under any conditions occurs. Management may prohibit discharge or certain polluting activities. TMDLs would need to assure no measurable increase in pollutant loading.

These reservoirs have been placed in Tier II. This provision mandates that existing water quality be maintained unless specific social and economic considerations are documented. These TMDLs will

[10] From the hypolimnion, the layer of water in a thermally stratified lake that lies below the thermocline, is non-circulating and remains perpetually cold.

result in the protection of existing beneficial uses, which conforms to Missouri's Tier I anti-degradation policy.

Specific Criteria:
The impairment of this lake is based on exceedence of the general criteria contained in Missouri's Water Quality Standards, 10 CSR 20-7.031(3)(A) and (C). Here it states:

- Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
- Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.

The impairment is also based on influencing the specific criteria at 10 CSR 20-7.031(4)(F) on Taste- and Odor-Producing Substances.

Excessive algal growth is the impairment, yet Missouri has no specific criteria for algal growth. Since a TMDL is a mathematical calculation, algal growth must be tied to some factor that can be measured and therefore able to be used in calculations. This factor is the TMDL endpoint.

TMDL Endpoint Discussion:

Introduction

Water with detectable geosmin and 2-methylisoborneal (MIB) levels has a slight musty taste treatable through the application of activated carbon or strong oxidation processes such as ozone peroxide injection (McGuire and Gaston 1988). Removal efficiencies of advanced technology such as granular activated carbon and biofilters are often inconsistent (Terauchi et al. 1995, Ridal et al. 2001) and difficult to maintain. City Utilities of Springfield (CU) staff believe the introduction of powdered activated carbon (PAC) into raw intake water to be a reasonable treatment process and have had preliminary results of approximately 70 percent MIB removal in the 20 ppt (parts per trillion) range (J. Parker- City Utilities of Springfield, e-mail). However, due to the evolving and inconsistent nature of this approach, a TMDL endpoint cannot be based on treatment of taste and odor compounds. The taste and odor events have prompted resource managers to investigate, and mitigate where possible, those factors that affect the production of taste and odor substances.

It is generally established that cyanobacteria can dominate phytoplankton (tiny plants) communities in warm, nutrient-rich, eutrophic lakes (Reynolds 1984, 1987). Furthermore, blooms of the cyanophycae have been definitively linked to off-flavors in drinking water (Juttner 1995, Persson 1995). Factors and mechanisms (Hyenstrand et al 1998) affecting the frequency, intensity, and duration of cyanobacteria proliferations were discussed at an intergovernmental coordination meeting held November 8, 2002 (Appendix B). During this meeting, US Environmental Protection Agency (EPA), Missouri Department of Natural Resources (MDNR), and City Utilities of Springfield (CU) staff discussed the possibility of setting TMDL targets based on research conducted by Downing et al. (2001) and independent of treatment considerations per 10 CSR 20-7.031(4)(F). According to this research, suspended chlorophyll-a predicts the risk of cyanobacteria dominance better than nutrient ratios, phytoplankton biomass, or concentrations of nitrogen and phosphorus. Attendees of this meeting noted that the risk of cyanobacteria dominance exponentially increases in temperate lakes when chlorophyll-a exceeds 10 μg/L (micrograms per liter or parts per billion).

TMDL Endpoint Options

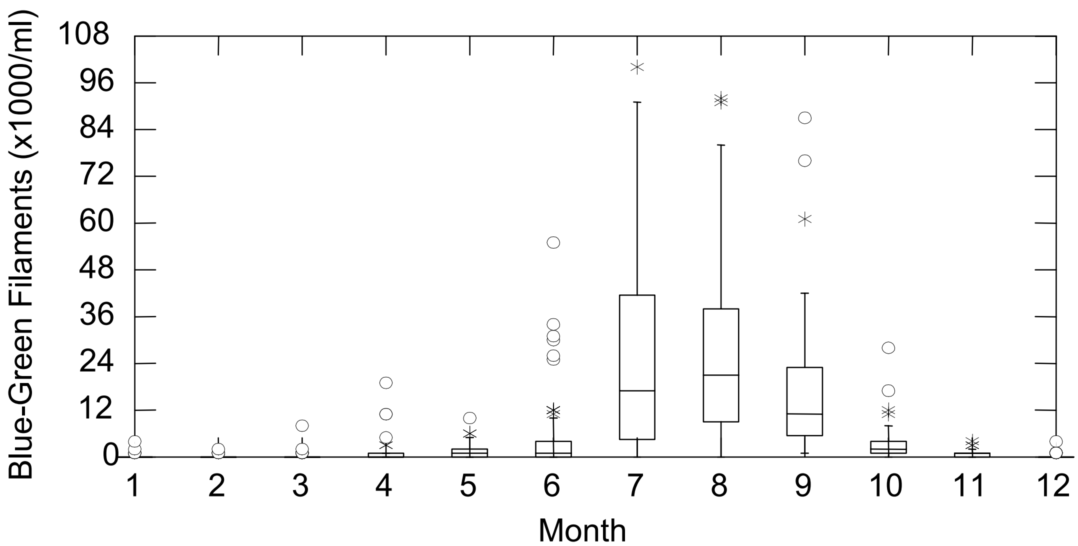
It should be noted that statistical analysis was hampered due to non-contemporaneous sampling protocols. In order to develop quantitative management tools, all data must be collected at the same time. Interpolated data may yield inaccurate conclusions as some parameters, such as chlorophyll-a, filament counts, and MIB levels, vary greatly from one day to the next. *Variance cannot be overstated considering the dynamic nature of the McDaniel Lake system*.

<u>1. Metabolite-Based Endpoint</u> (MIB or Geosmin)
An endpoint developed around substances causing the primary impairment initially represents the most direct and appropriate approach. As noted by John Parker of City Utilities of Springfield and confirmed by literature, MIB concentrations in drinking water above 4 – 9 ng/L often result in offensive tastes and odors. Unfortunately, nutrient reduction may not consistently result in less frequent taste and odor episodes as Knowlton (2002) demonstrated an insignificant relationship between interpolated MIB levels and total phosphorus. The use of MIB as an endpoint is further complicated because calibrated models such as Hydrological Simulation Program – Fortran (HSPF) do not account or simulate metabolite production in response to nutrient enrichment. Without a model, be it HSPF or regression, that significantly relates metabolites to a pollutant that can be allocated, an endpoint based on MIB or geosmin may not be very useful.

<u>2. Cyanobacteria-Based Endpoint</u> (Blue-Green Filament Counts)
As mentioned in the introduction, the presence of excessive cyanobacteria has been definitively linked to taste and odor problems. However, as we move farther away from the actual metabolite impairment (MIB, geosmin) more uncertainty is introduced when total cyanobacteria counts are used as indicators of potential MIB or geosmin contamination. We must recognize that several environmental factors, likely specific to each cyanobacteria species, affect the release of taste and odor producing compounds.

John Parker suggests that total blue-green filament counts exceeding 25,000/mL could result in taste and odor events. Based on data collected from 1983 to 2001, blue-green algae filament counts typically exceed 25,000/mL from July to September (Figure 2). Confounding this endpoint further are weakly correlated ($R^2 = <0.1$) relationships between blue-green filament counts and metabolite concentrations (MIB, geosmin). This may be due in part to low density cyanobacteria populations having the ability to produce relatively high extracellular metabolite concentrations (Rashash et al. 1995) in response to physiologic stress (Knowlton 2002). An endpoint based on blue-green filaments may not be useful because a meaningful quantitative link between blue-green filament counts and metabolite or nutrient concentrations is not available.

Figure 2. McDaniel Lake Blue-Green Filament Counts, 1983 – 2001



<u>3. Biomass Estimates</u> (Chlorophyll-a or Total Algae)
Literature supports management activities that minimize biomass or population densities in an effort to lessen the duration and intensity of objectionable blooms (Rashash et al 1995, Bowmer et al 1992, Naes et al 1988). Offensive metabolites are generally retained within cell boundaries (Rashash et al 1995, Bowmer et al 1992, Wu and Juttner 1988) unless environmental factors such as light or temperature cause the population to collapse, resulting in a taste and odor event.

Often the matter becomes a discussion of risk and those factors that contribute to the potential of harmful blooms and metabolite build-up. Indeed, managing taste and odor problems is rarely a pro rata reduction in any one causal variable, but rather a process of minimizing risks.

Studies by Trimbee and Prepas (1987) and Downing et al. (2001) considered the relative proportion (percentage) of the algal community composed by cyanobacteria as a useful indicator of potential taste and odor problems. Should environmental conditions initiate the collapse of a cyanobacteria population, it is assumed a community initially composed of proportionately higher cyanobacteria poses a greater threat to drinking water supplies. This assumption is supported by logistic regression (McFaddens' $R^2 = 0.096$, $p = 0.0000$) of MIB and percent cyanobacteria data from McDaniel Lake. However, no significant relationships exist that relate percent cyanobacteria ("blue-green index" from Trimbee and Prepas 1987) to chlorophyll, total algae, or total phosphorus.

It should be noted that Downing et al (2001) excluded lakes that were being manipulated or managed from the analysis. This may account for dissimilar relationships between McDaniel Lake and those used in his work.

<u>4. Reference Condition Approach</u>
Per US EPA guidelines, the 25th percentile of data from a waterbody of interest can be interpolated with the 75th percentile of data from a reference waterbody to arrive at nutrient targets. In 2001, the

Missouri Department of Natural Resources and the Environmental Protection Agency Region 7 contracted with the University of Missouri- Columbia (UMC) to identify reference lakes in Missouri. A list of lakes and accompanying data were made available to department staff, but no quantitative information was offered that supported these lakes being identified as reference conditions. Based on a subset of these data, the reference condition approach yields a chlorophyll-a target of 9.7 μg/L for McDaniel Lake. Assumptions inherent to this approach are: (1) reference conditions are free from taste and odor problems and (2) that the reference lakes chosen by UMC are indeed representative of least impacted conditions.

McDaniel Lake Endpoint

Given the options above, available literature and experts in limnology suggest the biomass estimate endpoint as the best possible approach toward minimizing the risks of taste and odor problems. Literature tells us that nutrient availability, namely phosphorus, will ultimately control the algal carrying capacity of McDaniel Lake. Therefore, in an effort to control biomass at levels that reduce the risk of cyanobacteria proliferation, **total phosphorus loading shall be allocated so that chlorophyll-a near the dam does not exceed 10 μg/L** (Downing et al. 2001).

3. CALCULATION OF LOAD CAPACITY

Load capacity is defined as the maximum pollutant load that a waterbody can assimilate and still attain water quality standards. It is equal to the sum of the Load Allocation (LA), the Wasteload Allocation (WLA) and the Margin of Safety (MOS) and can be expressed as an equation:

$$\mathbf{LC = LA + WLA + MOS}$$

In this TMDL, the WLA is zero (Section 5) so the equation becomes:

$$\mathbf{LC = LA + MOS}$$

The formula for calculating a load in pounds per day is as follows:
LC = (concentration of pollutant)(a constant used to convert to pounds per day)(flow in ft^3/sec)

Filling in the formula above by using an estimated flow of 14.3 ft^3/s from the McDaniel Lake watershed for the period from 1983-2002 and the target total phosphorus concentration of 26.68 μg/L (Table 1, Section 4 below) yields:

$$\mathbf{LC = 26.68\ \mu g/L * .005395 * 14.3\ ft^3/sec = 2.06\ pounds\ per\ day\ phosphorus}$$

Modeling Objective:

Many natural processes take place within McDaniel Lake. Due to the complexity of these processes and the lack of sufficient data to model them, for the purposes of this TMDL it becomes necessary to consider McDaniel Lake as a “black box”. The lack of adequate spatial (three-dimensional) and temporal (time) data within the lake limited the use of other available models (i.e., BATHTUB) to reliably predict the correlation between watershed loading and lake response. Therefore, the department chose an approach that was simple and solely based on a statistical interpretation of the data. An Ordinary Least Squares (OLS) linear regression approach was developed using statewide lake data collected by Dr. Jack Jones of the University of Missouri-Columbia. Statewide lake data were included in the analysis in order to increase the reliability and applicability of the model.

Simple linear regression illustrates the relationship between two sets of data, and the regression equation can be used to predict at a given confidence level values of one variable if the other is known. In this case, the linear regression equation describes the relationship between in-lake concentrations of chlorophyll-a (Chl-a) and total phosphorus (TP). The known McDaniel Lake target value of 10 μg/L chlorophyll-a will be used in the linear regression equation to determine the target total phosphorus concentration. Once the target total phosphorus concentration is determined, a target total phosphorus loading to McDaniel Lake can be calculated. The existing total phosphorus loading to McDaniel Lake can also be calculated using this method and concentrations of Chl-a and TP from a fixed point in the lake (sampling site near the Dam).

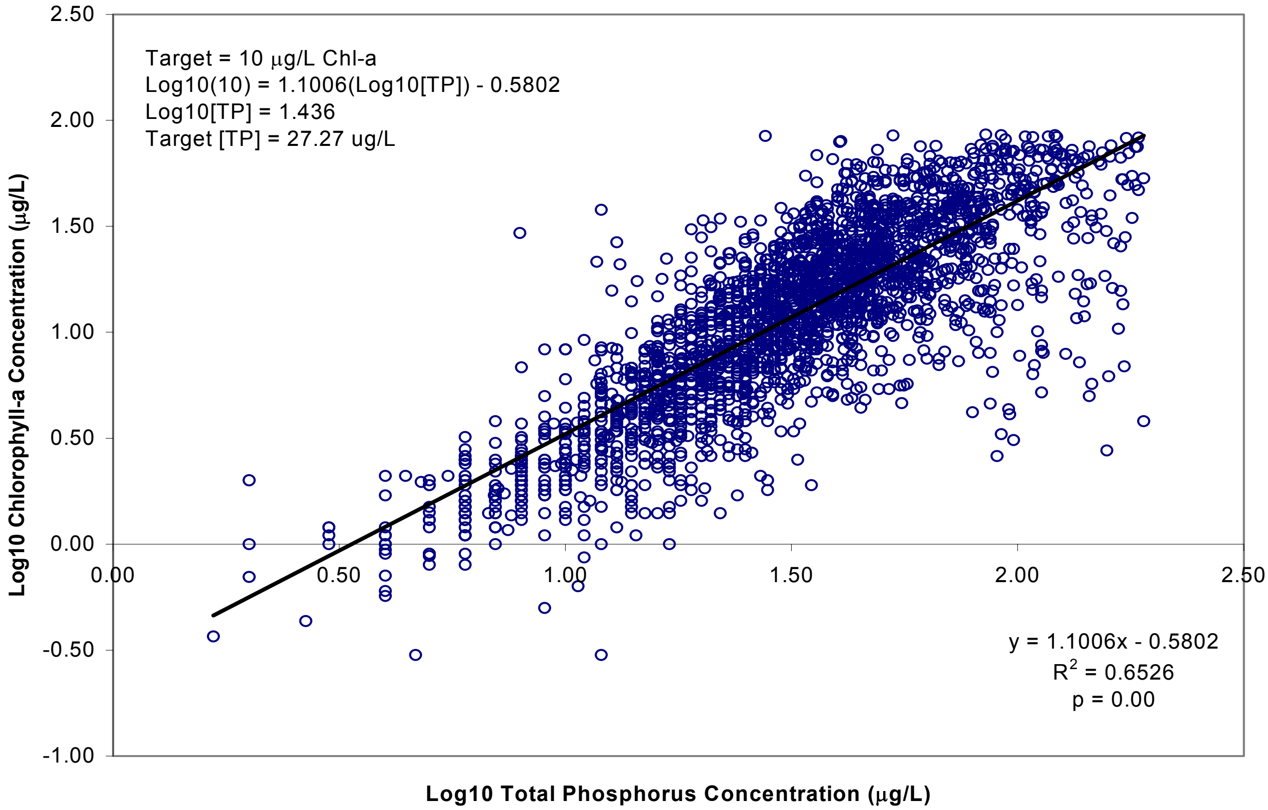
4. LOAD ALLOCATION (NON-POINT SOURCE LOAD)

The Load Allocation (LA) portion of a TMDL is the maximum allowable amount of pollutant loading that can be assigned to nonpoint sources.

McDaniel Lake receives water from its own watershed and indirectly from Stockton Lake. Water from Stockton Lake is pumped to Fellows Lake to augment its water level. If additional water is desired in McDaniel Lake, some or all of Stockton Lake pumpage is shunted via the Little Sac River directly into McDaniel Lake. Fellows Lake itself also has a bypass function allowing water to be discharged from the lake into the Little Sac River, which eventually flows downstream to McDaniel Lake. A number of wells in the area have been employed in the past to supplement McDaniel Lake's water supply, but this has not been done since the Stockton Lake pipeline came online in late 1996.

As mentioned in the TMDL endpoint discussion, taste and odor problems seem to occur within McDaniel Lake when blue-green algae filament counts exceed 25,000/mL. According to Figure 2, blue-green filament counts typically exceed 25,000/mL from July to September. Using data collected by the University of Missouri-Columbia (Appendix C), a linear regression model relating July-September chlorophyll-a and total phosphorus (TP) was developed using statewide data from 1976 to 2002 (Figure 3).

Figure 3. Statewide Lake Linear Regresssion Model, July-September, 1976-2002



The relationship in Figure 3 predicts that an in-lake total phosphorus concentration of 27.27 μg/L will yield a concentration of 10.0 μg/L chlorophyll-a during critical conditions July through September.

<u>Confidence Interval for the Mean Response</u> (Chlorophyll-a)
For the purposes of this TMDL, the confidence interval for the mean response represents the best estimate of mean chlorophyll-a expected at a given value of total phosphorus. Taking the 95th percentile confidence interval ensures, with 95 percent confidence, that the mean chlorophyll-a response for a given total phosphorus value falls within the bounds of the confidence interval. Individual values of chlorophyll-a are expected to vary over a much broader range called the prediction interval. Because the larger range of prediction interval values results in predicted concentrations of chlorophyll-a that fall above, as well as below, the target value, the 95th percentile confidence interval will be used to determine the most conservative target total phosphorus value. The 95th percentile confidence interval around the statewide lake Log_{10} chlorophyll-a target mean response is 1.00 $\pm$ 0.0105 μg/L, which corresponds to a Log_{10} total phosphorus target value of 1.44 $\pm$ 0.0095 μg/L.

The Chl-a target, the target's upper and lower 95th percentile confidence limits, and associated total phosphorus (TP) values are found in Table 1.

Table 1. Chlorophyll-a Target and 95th Percentile Confidence Interval (CI) Results

	Chl-a LT (μg/L)	TP LT (μg/L)	Chl-a (μg/L)	TP (μg/L)
Target	1.0000	1.4358	10.0000	27.2748
Upper 95% CI	1.0105	1.4453	10.2448	27.8808
Lower 95% CI	0.9895	1.4262	9.7611	**26.6821**

LT = Log-Transformed

Existing average total phosphorus and chlorophyll-a concentrations were calculated using data collected by the City Utilities of Springfield and the University of Missouri-Columbia (Appendix D). Available data sets were not subdivided according to management regimes because no time trends were detected for the ratio of chlorophyll-a to total phosphorus (r^2 =0.0019, p=0.29) in July through September data. Data from City Utilities of Springfield and University of Missouri-Columbia were pooled because matched comparison tests did not indicate significant difference between the data sets (Wilcoxon Rank Sum test=11, n=5).

After using the total phosphorus target of 26.68 μg/L to calculate the Load Capacity (Section 3), the target Load Allocation becomes a simple subtraction:

LA = LC – MOS

LA = 2.06 lb/day – 0.048 lb/day

LA = 2.01 pounds per day

Given an approximate existing total phosphorus load to McDaniel Lake of 3.36 lbs/day, a 40 percent reduction in total phosphorus is necessary to achieve the target load of 2.01 lbs/day. The steps and values used to determine loading and percent reduction of total phosphorus can be found in Appendix E.

Therefore, to achieve a chlorophyll-a target concentration of 10 μg/L at McDaniel Lake's dam, total phosphorus loading to the lake should be reduced by 40 percent.

5. WASTE LOAD ALLOCATION (POINT SOURCE LOADS)

The Wasteload Allocation (WLA) is the maximum allowable amount of the pollutant that can be assigned to point sources. There are presently five point sources in the McDaniel Lake watershed. These point sources are shown below in Figure 5 and listed in Table 2. None of the permits include nutrient (total nitrogen, total phosphorus, or ammonia) monitoring or effluent limits. The combined design flow for three of the five facilities (two do not have a design flow noted) is 0.0135 ft^3/s, or less than one-tenth of one percent of the total watershed flow. This flow equates to 8,721 gallons per day. Since the combined contribution of these discharges across the entire watershed is so small, it is not expected to impact the methods chosen to address the problem. These facilities will initiate a total phosphorus monitoring program as appropriate. **The WLA for this TMDL is zero pounds per day.**

Figure 5. Map of Watershed with Facility Locations

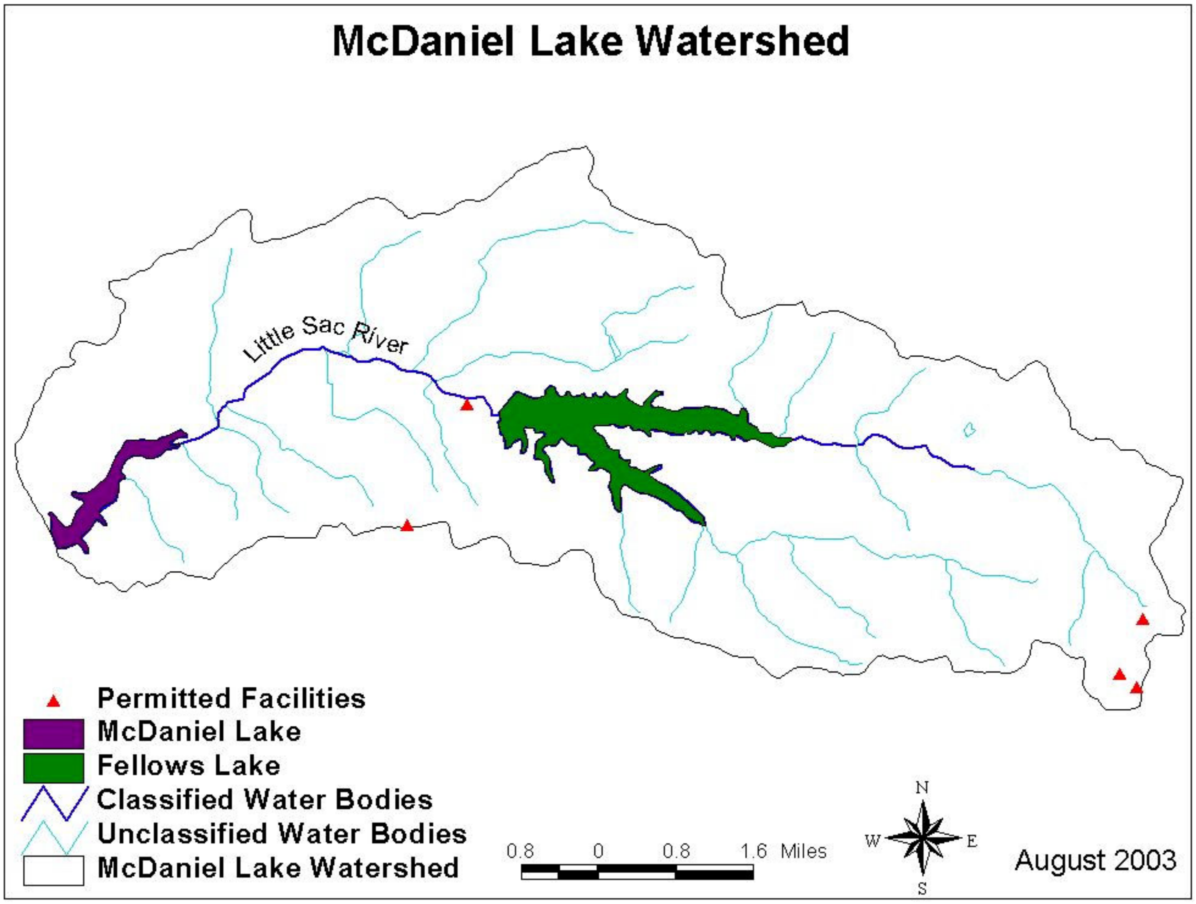


Table 2. List of Facilities in Watershed

Facility Name	Permit #	Design Flow (ft^3/s)
Travel Centers of the Ozarks, Inc.	MO-G140008**	0.0002
Nuccitelli Pipeline Alternate Discharge	MO-G690016**	No data
DD 125 Development	MO-R104087***	No data
Git-n-Go Store #86	MO-0113123****	0.0009
Pleasant View School	MO-0124331****	0.0124
Total		0.0135

**Missouri State Operating Permit—general
*** Missouri State Operating Permit—storm water
**** Missouri State Operating Permit—site specific

6. MARGIN OF SAFETY (MOS)

A Margin of Safety (MOS) is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

(1) Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
(2) Implicit - Incorporate the MOS as part of the design conditions for the waste load allocation and the load allocation calculations by making conservative assumptions in the analysis.

The Margin of Safety for this TMDL is both implicit and explicit. It is implicit in the fact that the linear regression of all the state-wide data was used in the analysis, instead of using the average TP concentration of lakes state-wide that corresponds to the target Chl-a concentration of 10 µg/L. As shown in Table 3, the average TP of 56.3 µg/L corresponds to 10 µg/L Chl-a. The resulting in-lake TP concentration target is about 50 percent lower using the regression analysis rather than an average value. This conservative option increases the MOS.

Table 3. Comparison of Targets

Comparison of the chosen TP target (26.68 µg/L) with other alternatives			
Chl-a (µg/L)	Number of samples	Average TP (µg/L)	% more than TP target (26.68 µg/L)
10	21	56.3	53%
9 to 10	177	57.59	54%
9.5 to 10	101	59.5	55%
9.5 to 10.5	162	65.2	59%

The MOS is also explicit by matching the lower 95th confidence of total phosphorus target concentration with the in-lake Chl-a target concentration of 10 µg/L (Table 1, Section 4). **Numerically, this accounts for an allocation of 2.4 % of the total load (or 0.048 lb/day) to MOS.**

7. SEASONAL VARIATION

The TMDL target was derived using July through September data when taste and odor events in McDaniel Lake were most likely to occur. By using data from this most problematic period instead of the entire year, the target is meant to prevent taste and odor occurrences year-round. If a phosphorus limit were instituted for the growing season only, it would ignore the effects of nutrient re-suspension in the water column within McDaniel Lake. For this reason, it is recommended that the 10 µg/L chlorophyll-a target be in effect year-round.

8. MONITORING PLANS FOR TMDL UNDER THE PHASED APPROACH

Phase I of this TMDL is to enhance City Utilities' current McDaniel Lake monitoring efforts and initiate the implementation plan. The TMDL monitoring plan will aid in determining the relationship between the potential causes of the taste and odor events (MIB and geosmin), the organisms that produce the MIB and geosmin (cyanobacteria), and the nutrients (phosphorus and nitrogen) that feed the cyanobacteria. Because an appropriate lake model may be utilized in Phase

II of this TMDL, these data will serve as the foundation with which to evaluate the implementation efforts in the McDaniel Lake watershed.

City Utilities of Springfield currently monitors McDaniel Lake as part of their source water monitoring program. Below is a list of parameters sampled at each site, sampling frequency, and site locations (Tables 4, 5 & 6).

Table 4. Current CU of Springfield McDaniel Lake Intake Sampling at the Dam (MDL001)

McDaniel Lake Intake Parameters	Number of Samples		
	Weekly	Monthly	Quarterly
Alkalinity	1		
Calcium	1		
Calcium Hardness	1		
Coliform	1		
Common Ions*		1	
Common Metals*		1	
Conductivity	1		
Fecal Coliform	1		
Geosmin/MIB	Sampled as needed		
H/P EPA 504 "DBCP"			1
H/P EPA 505 "Aldrin"			1
H/P EPA 507 "Alachlor"			1
pH	1		
Quarterly Metals***			1
Solids, Total Dissolved			1
Solids, Total Suspended			1
Target pH	1		
Temperature	1		
Threshold Odor	1		
Total Hardness	1		
TOC	1		
Turbidity	1		
Total Phosphate as P	1		
Number of sampling events per year	52	12	4

*Bromide, chloride, fluoride, nitrate, nitrite, orthophosphate, & sulfate
**Copper, iron, lead, manganese, sodium, & zinc
***Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, molybdenum, nickel, potassium, selenium, silver, & thallium

Table 5. Current CU of Springfield McDaniel and Fellows Lakes Watershed Samples Parameters (Locations in Table 6)

Lakes Watershed Parameters	Number of Samples		
	Weekly	Monthly	Quarterly
Common Ions*		3	
Common Metals**		3	
Chlorophyll-a		3	
Dissolved Oxygen		8	
Phytoplankton		9	
Total Phosphate as P		39	
Temperature		104	
Zooplankton		9	
Number of sampling events per year		9	

*Bromide, chloride, fluoride, nitrate, nitrite, orthophosphate, & sulfate
**Copper, iron, lead, manganese, sodium, & zinc

Table 6. Current CU of Springfield McDaniel and Fellows Lakes Watershed Sample Sites

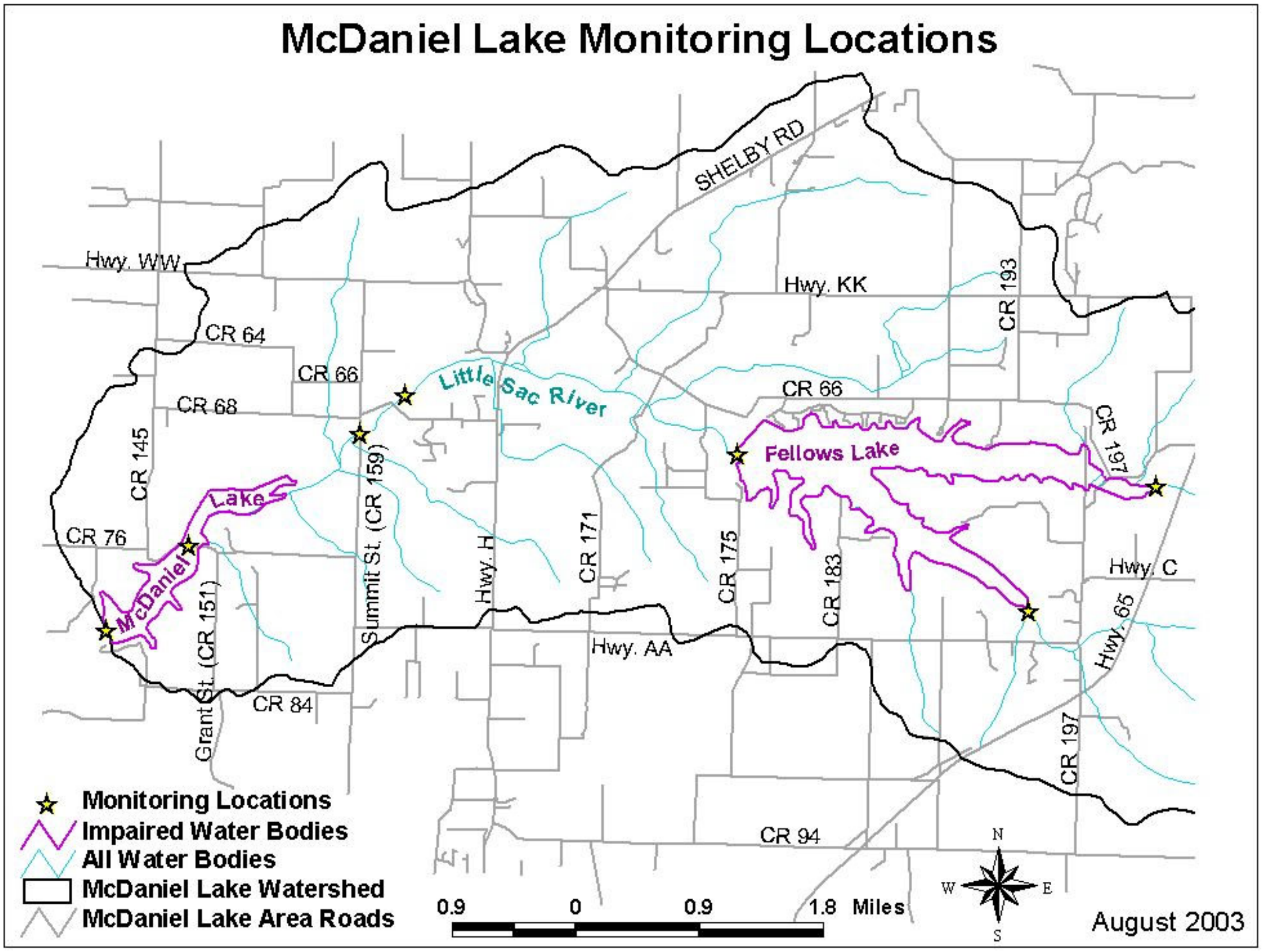
Lakes Watershed Sample Site Identification	
MDL-010	McDaniel Lake, top and bottom
FLL-014	Fellows Lake, top and bottom
LSR049	Little Sac River above McDaniel Lake
LSR060	Little Sac River near AG319 site, R16 tributary
NBC040	North Branch to Fellows Lake of Little Sac River
SBC040	South Branch to Fellows Lake
FLT020	Small Tributary to Fellows Lake from the north, above the Causeway
STL155	Stockton Lake, Highway 245 Bridge, top and bottom
LSR210	Little Sac River above Stockton Lake, Highway 215 West to Morrisville

The TMDL monitoring plan will consist of the extensive sampling efforts already being conducted by CU's Blackman Laboratories staff, as shown above. CU has agreed to collect their samples on the same day and as near to the same time as feasible. Particularly samples for chlorophyll-a, total phosphorus, water temperature, and Secchi depth/turbidity at the first seven sites listed in Table 6 (above) must be taken on the same day. If CU happens to be taking geosmin/MIB samples, those should be taken at the same time as those listed above. CU has also agreed to share this and other monitoring information with the department quarterly. These data will be used to assess TMDL implementation and may lead to a revision in the water quality target in Phase II if taste and odor events within McDaniel Lake persist. Furthermore, CU agrees to share information regarding taste and odor events along with pumpage data/flushing rate into and out of McDaniel Lake.

The following monitoring plan, with recommended sites shown in Figure 6 and listed in Table 7 with monitoring parameters listed in Table 8, is designed to provide the optimal parameters for a study of this lake. Any institution with available funds and an interest in this TMDL is encouraged to follow and improve upon this plan. Any data submitted will supplement City Utilities of Springfield's extensive sampling efforts.

The McDaniel Lake TMDL recommended monitoring plan was developed to acquire a comprehensive knowledge of the watershed. Although not directly addressed in this TMDL, Fellows Lake is located in the McDaniel Lake watershed. Therefore, Fellows Lake contributes to the water quality and loading of McDaniel Lake and should be considered when looking for a solution to the problem.

Figure 6. Location of Monitoring Sites



CR = County Road

Table 7. Recommended McDaniel Lake Monitoring Sites

Sampling Sites			
Description	**Latitude**	**Longitude**	**Sample Type**
McDaniel Lake at Dam	37.29452	-093.31463	6 foot composite
McDaniel Lake at Grant Street Bridge*	37.30412	-093.30351	6 foot composite
McDaniel Lake at Summit Street Bridge*	37.31578	-093.28117	6 foot composite
Little Sac River above McDaniel Lake	37.31987	-093.27487	grab
Fellows Lake at Dam	37.31374	-093.23125	6 foot composite

Little Sac River above Northern Arm of Fellows Lake	37.31044	-093.17615	grab
Little Sac River above Southern Arm of Fellows Lake	37.29727	-093.19292	grab

*A sample taken from the middle of the bridge (equally spaced between the bridge pillars so as to not collect from a stagnant pool) and on the downstream side would be ideal for the department.

Table 8. Recommended Monitoring Parameters

McDaniel Lake TMDL Monitoring Plan		
Parameter	**# of Weekly Samples**	**Sampling Events**
Ammonia as N	1	52
Chlorophyll-a	1	52
Conductivity**	1	52
Cyanobacteria Count*	1	52
Dissolved Oxygen**	1	52
Geosmin and MIB*	1	52
Nitrite/Nitrate as N	1	52
Non-volatile Suspended Solids	1	52
Percent Cloud Cover or Percent Light	1	52
PH**	1	52
Phytoplankton	1	52
Secchi Depth or Turbidity	1	52
Total Nitrogen as N	1	52
Total Phosphorus as P	1	52
Volatile Suspended Solids	1	52
Water Temperature**	1	52
Total	15	

*As an alternativeGeosmin/MIB and Cyanobacteria counts may be monitored from June to October due to the high cost associated with those tests (20 samples). A sample once per month from November to May is also recommended (seven samples).
**Water temperature, dissolved oxygen, conductivity, and pH samples taken at each interval of the 6-foot composite would be suggested if the samples are taken in the field.

9. IMPLEMENTATION

There has already been a lot of work completed in this watershed to reduce the amount of nutrients reaching the lakes. The Fellows-McDaniel Lakes 319 Project was implemented between 1992-1998 by Watershed Committee of the Ozarks. This study was prompted by the taste and odor problems in the lakes and subsequent public concern. Phosphorus, because of its role in algae production, was the main nutrient of study. In this study there were five demonstration and monitoring sites in the Fellows-McDaniel watershed, and in all cases improvement was recorded. In some cases, the improvement was dramatic. Nutrient and sediment loading to tributaries, and ultimately to the Little Sac River, was reduced, and dairy operations there rediscovered economic viability. In addition, aesthetics and habitat have improved considerably, and an increased diversity of species of birds and fish has been noted.

Another project in this watershed is an on-going Agricultural Nonpoint Source Special Area Land Treatment (AgNPS SALT) Project. This endeavor was one of the pilot projects under the SALT program. It was started in 1999 and will end July 1, 2004. Among the Best Management Practices initiated by this project are:

- 22,000 feet of riparian protection
- Seeding warm season grasses with grazing systems
- Water development for grazing systems (a four pasture system)
- Other alternative watering systems
- Installing 72 water tanks
- Leveling and reseeding old, eroded terraces
- A child education program, reaching over 2,000 school children so far

The Greene County Soil and Water Conservation District is currently managing this SALT Project and plans to apply for more 319 funds in the next Request For Proposals call in spring 2004.

These projects have been quite successful. In fact, CU reports there are enviably low levels of phosphorus in McDaniel Lake (35 to 45 µg/L TP). Nevertheless, excessive algae still causes the taste and odor problems the lakes are experiencing. More reductions in P need to be made to achieve the goal of 10 µg/L Chl-a.

To accomplish this, one approach being considered is to create a wetland at the head of McDaniel Lake and use aquatic plants to take up extra nutrients. To discover the feasibility of such an approach, the Watershed Committee of the Ozarks (WCO) and City Utilities have agreed to move forward with a demonstration project using one of the coves in the lake. This project will hopefully demonstrate the effectiveness of aquatic plants and can then be expanded.

Another approach will be to try again to reduce nutrients from on-site septic systems. The WCO anticipates receiving a 319 grant next spring (2004) that contains an on-site wastewater component. This will provide funds to:

a) Construct an on-site wastewater training center at Valley Water Mill. This center will provide a place to train on-site system installers, inspectors and maintenance personnel. The grant will also provide for a "non-point source educator" position. This person will develop training methods, materials and facilities for the center. Greene County alone now has about 200 certified installers. Greene County Resource Management, the Springfield-Greene Co. Health Department, Springfield Public Works and the WCO will plan the training center.
b) Conduct on-site wastewater "field days." These are essentially media events that call attention to the need to provide routine inspection and maintenance of on-site systems,
c) Provide 100 "coupons" for half-off the cost of routine inspection and maintenance--again, a media focused effort to encourage maintenance.
d) Rehabilitate two failing septic systems for demonstration purposes. These will provide sites for field visits, field trips and monitoring efforts.

These four activity areas will be focused in Greene County, but the committee might also focus their efforts more particularly in the McDaniel Lake watershed, since this is a primary area of concern for City Utilities and the department. In addition, existing septic systems need to be

inspected and maintained periodically for proper functioning. Strategies are being looked at to address non- or improperly functioning systems.

Additional Thoughts:
As summarized by Knowlton (2002), there seems to be little evidence in the way of quantitative relationships that predict cyanobacteria bloom intensities in McDaniel Lake. At this time, the department cannot say with any certainty that a 39 percent reduction in phosphorus will result in fewer taste and odor occurrences *based on available data*. Despite reductions in total phosphorus from the McDaniel Lake watershed over time, taste and odor problems persist. While the 10 µg/L chlorophyll-a target is the ultimate goal of this TMDL, future monitoring may indicate a different end point is more appropriate. Due to the phased nature of the TMDL process, if taste and odor problems continue to persist in McDaniel Lake, this TMDL will be re-opened and re-evaluated.

10. REASONABLE ASSURANCES

The Watershed Committee of the Ozarks is an established, locally run watershed group that has been actively working in the Springfield area since 1984. It has the people and expertise to facilitate or conduct water quality improvement projects. There is currently a "Water Quality Planning Group" operating as part of WCO's Vision 20/20 comprehensive planning effort in Springfield and Greene County. This group is considering many aspects of water quality management and improvement, including a look at the on-site wastewater system maintenance and management issues. It is possible that a more forceful attempt will be made to require periodic inspection and maintenance of on-site systems.

Greene County itself has aggressive ordinances and policies related to the installation of new on-site wastewater systems, including soil and site evaluation procedures that preceded state law. This includes setback provisions for water-supply lakes and streams. McDaniel Lake watershed is entirely within Greene County, so the whole watershed is covered by these ordinances.

Also, City Utilities of Springfield has the ability and expertise to conduct monitoring, analyze samples and accomplish water quality improvement projects. CU manages the lakes and is actively pursuing a method that will work to eliminate the taste and odor problem that has been plaguing them for years. Their 2004 lake management plans include:

- > Coordinate with WCO to install wetland practices and aquatic plants on CU property.
- > Refine and evaluate chemical treatment of lakes to target problematic species.
- > Biweekly sampling at strategic sample points throughout the lake, focusing on transient incubator conditions throughout the warm seasons.
- > Network with experienced limnologists regarding improved sampling, speciation and enumeration techniques of algae.

Finally, the Department of Natural Resources has the authority to write and enforce Missouri State Operating Permits. Inclusion of effluent limits into a state permit, and daily monitoring with monthly reports, should provide reasonable assurance that water quality standards will be met.

11. PUBLIC PARTICIPATION

A meeting was held July 24, 2003 to present to the public the taste and odor problem, what City Utilities has been doing to manage the lake, what is involved in developing a TMDL and the specific TMDL target for the lakes. This meeting also provided local citizens an opportunity to have input into the TMDL implementation plan. The TMDL presentation was given again a week later to the Watershed Committee of the Ozarks on August 1, 2003. The Implementation Section (Sec. 9) lists what this committee is undertaking to improve conditions in the lakes.

These water quality limited segments are included on the approved 1998 303(d) list for Missouri. The Missouri Department of Natural Resources, Water Pollution Control Program, developed this TMDL. A 30-day Public Notice period is being held from November 21 to December 21, 2003. Groups that received the public notice announcement include:

- The Missouri Clean Water Commission
- The Water Quality Coordinating Committee
- The TMDL Policy Advisory Committee
- Watershed Committee of the Ozarks
- Stream Teams in the lakes' watershed (12)
- The appropriate legislators (10)
- Others that routinely receive the public notice of Missouri State Operating Permits

A copy of the notice, the comments received and the department responses will be placed in the McDaniel Lake file.

12. ADMINISTRATIVE RECORD AND SUPPORTING DOCUMENTATION

An administrative record on the McDaniel Lake TMDL has been assembled and is being kept on file with the Missouri Department of Natural Resources. It includes the following:

- Missouri State Operating Permits for the facilities listed in Section 5
- 319 Project 1982-88
- Upper Little Sac River AgNPS SALT Project Management Plan
- Limnological Evaluation of Fellows and McDaniel Lakes, Missouri. (University of Missouri)
- Statewide Lake Data from the University of Missouri-Columbia
- Public Notice announcement
- McDaniel Lake Information Sheet

13. APPENDICES

Appendix A – Land Use Types for the Fellows and McDaniel Lakes Watershed
Appendix B – Fellows and McDaniel Meeting Summary
Appendix C – Statewide Lake Data – University of Missouri at Columbia
Appendix D – McDaniel Lake Data from City Utilities of Springfield and University of Missouri-Columbia
Appendix E – Load Allocation Calculations

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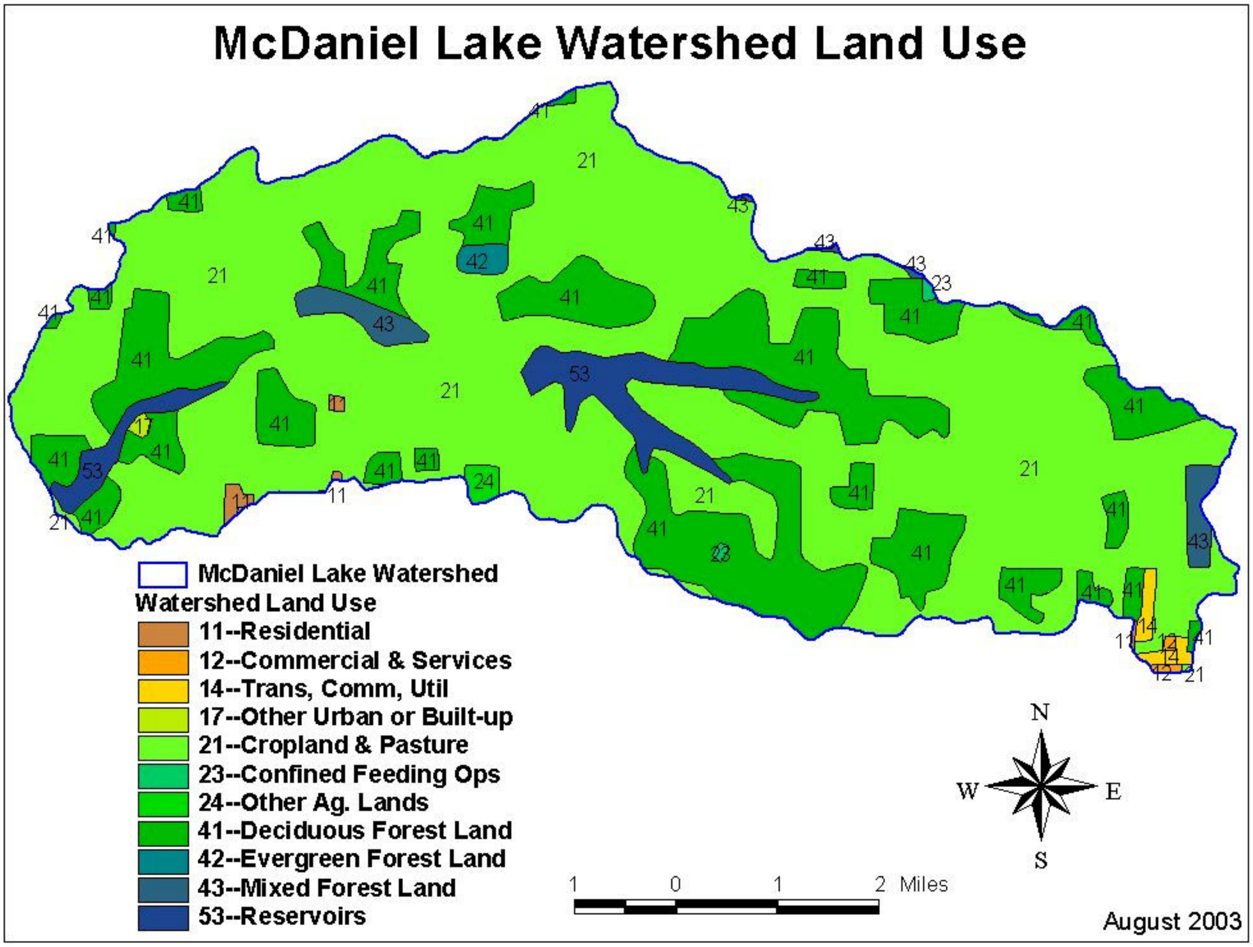
Appendix A

Land Use Map
Fellows and McDaniel Lakes Watershed



Appendix B

Fellows and McDaniel Meeting Summary
November 8th, 2002

Staff from concerned agencies (DNR, EPA, Springfield City Utilities and Univ. of Missouri - Columbia) met in Jefferson City Nov. 8th, 2002 to discuss issues relating to the Fellows and McDaniel Lake TMDL. The purpose of the meeting was to (1) discuss progress and results of projects sponsored by US EPA and Springfield City Utilities and (2) determine phase I TMDL endpoints and/or subsequent loading reductions.

BACKGROUND INFORMATION
Dr. Matt Knowlton (2002) provided a summary of limnological characteristics of Fellows and McDaniel lakes. He characterized nutrient reductions as 'blunt instruments' in reducing taste and odor problems due to interactions of light, temperature, stratification, nutrient ratios, and weak predictive correlations. Dr. Knowlton explained that additional research on algae communities in these lakes might reveal a more precise means of controlling taste and odor outbreaks.

Steve McIntosh presented the results of rainfall-runoff simulations from the Hydrological Simulation Program Fortran (HSPF) model. Model assumptions and subsequent uncertainties were discussed. Among these uncertainties are spillway height, thermal stratification, springflow contributions, and target endpoint variation. Results from this effort will allow managers to allocate funding for nutrient control measures to critical sub-watersheds.

Norman Youngsteadt discussed the effects of internal nutrient loading, antecedent light and temperature conditions, external nutrient enrichment as well as grazing by cladoceran plankters in predicting taste and odor problems in McDaniel Lake. Mr. Youngsteadt concluded that no one factor can be consistently correlated with taste and odor events in Fellows or McDaniel Lakes. Of note, MIB concentrations were weakly correlated with suspended cyanobacteria filament counts (r^2 <0.1) and insignificantly related to total phosphorus or chlorophyll a. This may indicate that MIB production is either specific to a few alga genera or mechanisms that control MIB release are not density dependent.

ENDPOINT DISCUSSION
City of Springfield staff indicated that the long-term goal of the TMDL should be zero taste and odor episodes in Fellows and McDaniel Lake. However, most attendees doubted the feasibility of such an endpoint as even relatively nutrient-poor reservoirs occasionally experience taste and odor problems. City Utility staff believes that goal(s) for Phase I should include, at the minimum, no increase in nutrient loading from contributing watersheds.

Further discussion by attendees lead to suggestions that an approach using research conducted by Downing et al. (2001) be used to develop the TMDL target. This approach, used by EPA Region 7 nutrient criteria workgroup, employed phosphorus, nitrogen, and chlorophyll a estimates to predict the risk of cyanobacteria dominance in temperate lakes. It was offered that the TMDL target should be expressed as chlorophyll a, as measured by a six-foot composite sample taken near drinking water intakes.

Appendix C

Statewide Lake Data (UMC study)

		TP (ug/L)	Log10 TP	CHL (ug/L)	Log10 Chl-a	**SSx**	**SSy**	**SSxy**
Average		41.55	1.51	18.49	1.08			
Min		1.67	0.22	0.30	-0.52			
25th percentile		20.00	1.30	6.20	0.79			
Median		34.00	1.53	13.57	1.13			
75th percentile		52.00	1.72	25.00	1.40			
Max		190.00	2.28	85.70	1.93			
Sum						257.58	478.14	283.49
n	2464							
df	2462							
b	1.10							
s2	0.07							
s	0.26							
95 %tile: t = (infinity)	1.96							
MOS	0.01							
y+	1.01							
y-	0.99							

$$\hat{y} \pm ts\sqrt{1/n + \frac{(x_o - \overline{x})^2}{SS_x}}$$

		TP (ug/L)	Log10 TP	CHL (ug/L)	Log10 Chl-a			
Target		27.27	1.44	10.00	1.00			
Upper 95% CI		27.88	1.45	10.24	1.01			
Lower 95% CI		26.68	1.43	9.76	0.99			

(For a complete list of the data, please contact the Missouri Department of Natural Resources, Water Pollution Control Program, Water Quality Section. The data from statewide lakes is too large to include in this document.)

Appendix D

McDaniel Lake Data from City Utilities of Springfield and University of Missouri-Columbia

Date	ORG	Total Phosphorus (μg/L)	Chlorophyll-a (μg/L)	log10 TP	log10 Chl-a
01-Jul-83	SPFUTIL	40.00	24.10	1.6021	1.3820
07-Jul-83	SPFUTIL	32.00	23.10	1.5051	1.3636
12-Jul-83	SPFUTIL	30.00	12.50	1.4771	1.0969
20-Jul-83	SPFUTIL	46.00	17.50	1.6628	1.2430
27-Jul-83	SPFUTIL	51.00	28.40	1.7076	1.4533
03-Aug-83	SPFUTIL	59.00	42.30	1.7709	1.6263
10-Aug-83	SPFUTIL	55.00	32.00	1.7404	1.5051
17-Aug-83	SPFUTIL	78.00	21.20	1.8921	1.3263
24-Aug-83	SPFUTIL	67.00	32.40	1.8261	1.5105
31-Aug-83	SPFUTIL	62.00	37.70	1.7924	1.5763
07-Sep-83	SPFUTIL	63.00	53.10	1.7993	1.7251
14-Sep-83	SPFUTIL	69.00	49.00	1.8388	1.6902
21-Sep-83	SPFUTIL	63.00	42.90	1.7993	1.6325
28-Sep-83	SPFUTIL	77.00	34.40	1.8865	1.5366
02-Jul-84	SPFUTIL	50.00	23.70	1.6990	1.3747
16-Jul-84	SPFUTIL	33.00	13.50	1.5185	1.1303
31-Jul-84	SPFUTIL	33.00	11.50	1.5185	1.0607
14-Aug-84	SPFUTIL	60.00	27.40	1.7782	1.4378
28-Aug-84	SPFUTIL	60.00	18.30	1.7782	1.2625
11-Sep-84	SPFUTIL	62.00	30.50	1.7924	1.4843
25-Sep-84	SPFUTIL	66.00	43.40	1.8195	1.6375
09-Jul-85	SPFUTIL	52.00	22.60	1.7160	1.3541
16-Jul-85	SPFUTIL	50.00	16.60	1.6990	1.2201
23-Jul-85	SPFUTIL	45.00	7.70	1.6532	0.8865
30-Jul-85	SPFUTIL	47.00	14.90	1.6721	1.1732
06-Aug-85	SPFUTIL	47.00	21.20	1.6721	1.3263
13-Aug-85	SPFUTIL	57.00	27.40	1.7559	1.4378
20-Aug-85	SPFUTIL	54.00	40.60	1.7324	1.6085
27-Aug-85	SPFUTIL	57.00	31.90	1.7559	1.5038
03-Sep-85	SPFUTIL	44.00	26.50	1.6435	1.4232
10-Sep-85	SPFUTIL	44.00	13.50	1.6435	1.1303
17-Sep-85	SPFUTIL	54.00	27.70	1.7324	1.4425
24-Sep-85	SPFUTIL	44.00	25.40	1.6435	1.4048
01-Jul-86	SPFUTIL	54.00	29.70	1.7324	1.4728
08-Jul-86	SPFUTIL	47.00	32.30	1.6721	1.5092
15-Jul-86	SPFUTIL	54.00	32.60	1.7324	1.5132
22-Jul-86	SPFUTIL	78.00	54.50	1.8921	1.7364
29-Jul-86	SPFUTIL	98.00	51.20	1.9912	1.7093
01-Aug-86	SPFUTIL	84.00	33.30	1.9243	1.5224
05-Aug-86	SPFUTIL	67.00	32.70	1.8261	1.5145
12-Aug-86	SPFUTIL	81.00	24.10	1.9085	1.3820
19-Aug-86	SPFUTIL	66.00	24.10	1.8195	1.3820
26-Aug-86	SPFUTIL	93.00	43.30	1.9685	1.6365
02-Sep-86	SPFUTIL	81.00	45.50	1.9085	1.6580
09-Sep-86	SPFUTIL	73.00	31.80	1.8633	1.5024
16-Sep-86	SPFUTIL	81.00	38.00	1.9085	1.5798

Date	ORG	Total Phosphorus (μg/L)	Chlorophyll-a (μg/L)	log10 TP	log10 Chl-a
23-Sep-86	SPFUTIL	69.00	22.60	1.8388	1.3541
07-Jul-87	SPFUTIL	57.00	34.10	1.7559	1.5328
14-Jul-87	SPFUTIL	61.00	53.50	1.7853	1.7284
21-Jul-87	SPFUTIL	61.00	33.30	1.7853	1.5224
28-Jul-87	SPFUTIL	51.00	25.90	1.7076	1.4133
04-Aug-87	SPFUTIL	54.00	39.60	1.7324	1.5977
11-Aug-87	SPFUTIL	56.00	45.40	1.7482	1.6571
18-Aug-87	SPFUTIL	45.00	32.20	1.6532	1.5079
25-Aug-87	SPFUTIL	58.00	35.70	1.7634	1.5527
01-Sep-87	SPFUTIL	44.00	25.70	1.6435	1.4099
08-Sep-87	SPFUTIL	54.00	34.80	1.7324	1.5416
22-Sep-87	SPFUTIL	44.00	29.60	1.6435	1.4713
29-Sep-87	SPFUTIL	46.00	28.60	1.6628	1.4564
05-Jul-88	SPFUTIL	35.00	20.90	1.5441	1.3201
12-Jul-88	SPFUTIL	63.00	29.60	1.7993	1.4713
19-Jul-88	SPFUTIL	41.00	26.50	1.6128	1.4232
26-Jul-88	SPFUTIL	57.00	24.20	1.7559	1.3838
02-Aug-88	SPFUTIL	41.00	30.70	1.6128	1.4871
09-Aug-88	SPFUTIL	44.00	45.00	1.6435	1.6532
16-Aug-88	SPFUTIL	40.00	39.80	1.6021	1.5999
23-Aug-88	SPFUTIL	58.00	56.20	1.7634	1.7497
30-Aug-88	SPFUTIL	63.00	66.40	1.7993	1.8222
06-Sep-88	SPFUTIL	57.00	34.40	1.7559	1.5366
13-Sep-88	SPFUTIL	46.00	27.20	1.6628	1.4346
20-Sep-88	SPFUTIL	50.00	28.60	1.6990	1.4564
27-Sep-88	SPFUTIL	56.00	55.10	1.7482	1.7412
11-Jul-89	SPFUTIL	41.00	26.50	1.6128	1.4232
17-Jul-89	UMC	46.00	22.20	1.6628	1.3464
19-Jul-89	SPFUTIL	39.00	30.80	1.5911	1.4886
25-Jul-89	SPFUTIL	47.00	18.40	1.6721	1.2648
01-Aug-89	SPFUTIL	43.00	50.60	1.6335	1.7042
15-Aug-89	SPFUTIL	36.00	16.60	1.5563	1.2201
22-Aug-89	UMC	42.00	19.60	1.6232	1.2923
29-Aug-89	SPFUTIL	37.00	13.60	1.5682	1.1335
10-Jul-90	SPFUTIL	41.00	23.20	1.6128	1.3655
11-Jul-90	UMC	36.00	12.40	1.5563	1.0934
24-Jul-90	SPFUTIL	34.00	19.00	1.5315	1.2788
07-Aug-90	SPFUTIL	24.00	18.90	1.3802	1.2765
08-Aug-90	UMC	34.50	13.00	1.5378	1.1139
21-Aug-90	SPFUTIL	34.00	28.70	1.5315	1.4579
04-Sep-90	SPFUTIL	26.00	15.10	1.4150	1.1790
09-Jul-91	SPFUTIL	39.00	16.40	1.5911	1.2148
10-Jul-91	UMC	26.00	14.90	1.4150	1.1732
23-Jul-91	SPFUTIL	54.00	29.00	1.7324	1.4624
30-Jul-91	SPFUTIL	38.00	24.40	1.5798	1.3874
07-Aug-91	UMC	35.50	22.05	1.5502	1.3434
12-Aug-91	SPFUTIL	41.00	35.40	1.6128	1.5490
10-Sep-91	SPFUTIL	41.00	15.70	1.6128	1.1959
25-Sep-91	SPFUTIL	23.00	14.10	1.3617	1.1492
15-Jul-92	SPFUTIL	33.00	8.90	1.5185	0.9494
15-Jul-92	UMC	31.00	16.60	1.4914	1.2201
22-Jul-92	SPFUTIL	34.00	17.80	1.5315	1.2504

Date	ORG	Total Phosphorus (μg/L)	Chlorophyll-a (μg/L)	log10 TP	log10 Chl-a
28-Jul-92	SPFUTIL	26.00	25.30	1.4150	1.4031
03-Aug-92	SPFUTIL	37.00	32.60	1.5682	1.5132
11-Aug-92	SPFUTIL	28.00	20.40	1.4472	1.3096
11-Aug-92	UMC	33.33	18.53	1.5229	1.2680
18-Aug-92	SPFUTIL	24.00	16.00	1.3802	1.2041
25-Aug-92	SPFUTIL	35.00	47.80	1.5441	1.6794
01-Sep-92	SPFUTIL	34.00	32.20	1.5315	1.5079
08-Sep-92	SPFUTIL	21.00	20.60	1.3222	1.3139
16-Sep-92	SPFUTIL	38.00	52.40	1.5798	1.7193
22-Sep-92	SPFUTIL	28.00	27.00	1.4472	1.4314
30-Sep-92	SPFUTIL	33.00	31.60	1.5185	1.4997
06-Jul-93	SPFUTIL	45.00	41.50	1.6532	1.6180
13-Jul-93	UMC	35.50	15.30	1.5502	1.1847
21-Jul-93	SPFUTIL	35.00	26.00	1.5441	1.4150
03-Aug-93	SPFUTIL	23.00	12.20	1.3617	1.0864
10-Aug-93	UMC	28.50	12.00	1.4548	1.0792
17-Aug-93	SPFUTIL	19.00	12.20	1.2788	1.0864
31-Aug-93	SPFUTIL	34.00	19.00	1.5315	1.2788
14-Sep-93	SPFUTIL	27.00	19.90	1.4314	1.2989
21-Sep-93	SPFUTIL	21.00	25.50	1.3222	1.4065
05-Jul-94	SPFUTIL	34.00	20.70	1.5315	1.3160
12-Jul-94	UMC	33.00	9.95	1.5185	0.9978
26-Jul-94	SPFUTIL	26.00	13.80	1.4150	1.1399
16-Aug-94	SPFUTIL	14.00	20.50	1.1461	1.3118
23-Aug-94	SPFUTIL	37.00	13.30	1.5682	1.1239
30-Aug-94	SPFUTIL	33.00	18.20	1.5185	1.2601
19-Sep-94	SPFUTIL	28.00	13.60	1.4472	1.1335
03-Jul-95	SPFUTIL	38.00	11.40	1.5798	1.0569
11-Jul-95	SPFUTIL	27.00	7.90	1.4314	0.8976
17-Jul-95	SPFUTIL	21.00	6.80	1.3222	0.8325
02-Aug-95	UMC	34.50	5.85	1.5378	0.7672
09-Aug-95	SPFUTIL	49.00	14.70	1.6902	1.1673
23-Aug-95	SPFUTIL	36.00	13.10	1.5563	1.1173
29-Aug-95	SPFUTIL	39.00	19.30	1.5911	1.2856
06-Sep-95	SPFUTIL	39.00	22.00	1.5911	1.3424
12-Sep-95	SPFUTIL	40.00	35.40	1.6021	1.5490
19-Sep-95	SPFUTIL	39.00	22.20	1.5911	1.3464
25-Sep-95	SPFUTIL	42.00	20.30	1.6232	1.3075
02-Jul-96	SPFUTIL	34.00	13.20	1.5315	1.1206
16-Jul-96	SPFUTIL	36.00	13.20	1.5563	1.1206
23-Jul-96	SPFUTIL	25.00	12.00	1.3979	1.0792
30-Jul-96	SPFUTIL	39.00	15.90	1.5911	1.2014
06-Aug-96	SPFUTIL	48.00	33.70	1.6812	1.5276
13-Aug-96	SPFUTIL	44.00	37.90	1.6435	1.5786
03-Sep-96	SPFUTIL	58.00	36.60	1.7634	1.5635
09-Sep-96	SPFUTIL	25.00	15.50	1.3979	1.1903
17-Sep-96	SPFUTIL	49.00	30.70	1.6902	1.4871
23-Sep-96	SPFUTIL	58.00	18.50	1.7634	1.2672
30-Sep-96	SPFUTIL	47.00	20.50	1.6721	1.3118
01-Jul-97	SPFUTIL	29.00	14.80	1.4624	1.1703
01-Jul-97	UMC	32.00	16.45	1.5051	1.2162
15-Jul-97	SPFUTIL	25.00	9.90	1.3979	0.9956

Date	ORG	Total Phosphorus (μg/L)	Chlorophyll-a (μg/L)	log10 TP	log10 Chl-a
28-Jul-97	SPFUTIL	30.00	18.50	1.4771	1.2672
29-Jul-97	UMC	32.00	31.95	1.5051	1.5045
05-Aug-97	SPFUTIL	40.00	29.40	1.6021	1.4683
19-Aug-97	SPFUTIL	45.00	44.00	1.6532	1.6435
02-Sep-97	SPFUTIL	39.00	18.40	1.5911	1.2648
16-Sep-97	SPFUTIL	38.00	36.70	1.5798	1.5647
30-Sep-97	SPFUTIL	43.00	27.40	1.6335	1.4378
07-Jul-98	SPFUTIL	27.00	15.30	1.4314	1.1847
21-Jul-98	SPFUTIL	39.00	17.60	1.5911	1.2455
21-Jul-98	UMC	28.00	16.90	1.4472	1.2279
04-Aug-98	SPFUTIL	32.00	22.00	1.5051	1.3424
11-Aug-98	UMC	23.50	11.50	1.3711	1.0607
18-Aug-98	SPFUTIL	28.00	16.20	1.4472	1.2095
25-Aug-98	SPFUTIL	42.00	12.00	1.6232	1.0792
08-Sep-98	SPFUTIL	34.00	16.80	1.5315	1.2253
22-Sep-98	SPFUTIL	30.00	19.80	1.4771	1.2967
29-Sep-98	SPFUTIL	43.00	31.40	1.6335	1.4969
20-Jul-99	SPFUTIL	21.00	6.40	1.3222	0.8062
27-Jul-99	SPFUTIL	30.00	13.70	1.4771	1.1367
03-Aug-99	SPFUTIL	37.00	13.70	1.5682	1.1367
03-Aug-99	UMC	28.00	23.20	1.4472	1.3655
10-Aug-99	SPFUTIL	33.00	13.30	1.5185	1.1239
17-Aug-99	SPFUTIL	38.00	22.50	1.5798	1.3522
24-Aug-99	SPFUTIL	34.00	11.50	1.5315	1.0607
31-Aug-99	SPFUTIL	40.00	7.10	1.6021	0.8513
07-Sep-99	SPFUTIL	56.00	30.00	1.7482	1.4771
14-Sep-99	SPFUTIL	47.00	18.50	1.6721	1.2672
21-Sep-99	SPFUTIL	30.00	22.60	1.4771	1.3541
28-Sep-99	SPFUTIL	24.00	21.40	1.3802	1.3304
18-Jul-00	SPFUTIL	76.00	65.40	1.8808	1.8156
18-Jul-00	UMC	66.50	95.05	1.8228	1.9780
25-Jul-00	SPFUTIL	55.00	36.30	1.7404	1.5599
01-Aug-00	SPFUTIL	73.00	51.60	1.8633	1.7126
08-Aug-00	SPFUTIL	43.00	24.20	1.6335	1.3838
08-Aug-00	UMC	46.00	35.00	1.6628	1.5441
15-Aug-00	SPFUTIL	39.00	32.30	1.5911	1.5092
17-Jul-01	SPFUTIL	43.00	19.70	1.6335	1.2945
17-Jul-01	UMC	46.00	44.88	1.6628	1.6520
07-Aug-01	SPFUTIL	35.00	8.50	1.5441	0.9294
07-Aug-01	UMC	27.50	13.83	1.4393	1.1408
14-Aug-01	SPFUTIL	38.00	14.60	1.5798	1.1644
21-Aug-01	SPFUTIL	39.00	9.50	1.5911	0.9777
28-Aug-01	SPFUTIL	32.00	5.20	1.5051	0.7160
11-Sep-01	SPFUTIL	38.00	12.50	1.5798	1.0969
25-Sep-01	SPFUTIL	40.00	25.30	1.6021	1.4031
09-Jul-02	SPFUTIL	33.00	6.40	1.5185	0.8062
16-Jul-02	SPFUTIL	43.00	14.50	1.6335	1.1614
23-Jul-02	SPFUTIL	44.00	21.10	1.6435	1.3243
23-Jul-02	UMC	29.00	15.95	1.4624	1.2028
30-Jul-02	SPFUTIL	39.00	30.10	1.5911	1.4786
12-Aug-02	SPFUTIL	42.00	35.10	1.6232	1.5453
13-Aug-02	UMC	35.00	29.75	1.5441	1.4734

Date	ORG	Total Phosphorus (μg/L)	Chlorophyll-a (μg/L)	log10 TP	log10 Chl-a
27-Aug-02	SPFUTIL	45.00	28.60	1.6532	1.4564
03-Sep-02	SPFUTIL	56.00	24.10	1.7482	1.3820
09-Sep-02	SPFUTIL	43.00	22.80	1.6335	1.3579
17-Sep-02	SPFUTIL	43.00	20.70	1.6335	1.3160
23-Sep-02	SPFUTIL	46.00	35.20	1.6628	1.5465
Mean		43.6006	25.5615	1.6156	1.3538

Appendix E

Load Allocation Calculations

The steps and values used in calculating the Total Phosphorus load reduction are as follows:

1. Average total phosphorus concentration for McDaniel Lake is 43.6 μg/L.

2. Estimate stream flow by drainage-area size
   USGS #06918740 Little Sac River near Morrisville, MO Drainage area = 151,680 acres
   Mean daily flow = 91.20 ft^3/sec

   (The flow data can be downloaded from the following website:
   http://nwis.waterdata.usgs.gov/mo/nwis/discharge?search_site_no=06918740&search_site_no_match_type=exact&format=station_list&sort_key=site_no&group_key=NONE&sitefile_output_format=html_table&column_name=agency_cd&column_name=site_no&column_name=station_nm&column_name=lat_va&column_name=long_va&column_name=state_cd&column_name=county_cd&column_name=alt_va&column_name=huc_cd&list_of_search_criteria=search_site_no)

   McDaniel Lake watershed - Drainage area = 23,776 acres

   (23,776 ac)/(151,680 ac) = 15.675%

   July-September 1983-2002 Flow Data
   (15.675%)*(91.20 ft^3/sec) = **14.30 ft^3/sec**
   McDaniel Lake watershed - **Est. mean flow = 14.30 ft^3/sec**

3. Use equation below with target TP concentration of 26.68 μg/L (from Table 1, Section 4) and the flow calculated in #2 above:
   TP Loading in pounds/day = (TP concentration in μg/L)*(0.005395)*(flow in ft^3/sec)
   0.005395 = the constant used when converting μg/L and ft^3/sec to pounds per day
   Target Loading in lb/day = 26.68 μg/L *0 .005395 * 14.30 ft^3/sec
   Target Loading or LC = 2.06 lb/day

4. Use equation below with current TP concentration of 43.6 μg/L (from # 1, above) and the flow calculated in #2:
   TP Loading in pounds/day = (TP concentration in μg/L)*(0.005395)*(flow in ft^3/sec)
   Current Loading in lb/day = 43.6 μg/L * 0.005395 * 14.30 ft^3/sec
   Current Loading = 3.36 lb/day

5. Determine the required load reduction.
   Use the next equation to calculate the percent reduction:
   [(Existing Load-LA)/Existing Load] = % TP reduction
   Note: The LA (2.01 lb/day) is the only variable of the LC that will be affected by the reduction.
   [(3.36-2.01)/3.36] = **40 % TP reduction**